

NEW ENGLAND SHELFBREAK FRONT "PRIMER" EXPERIMENT: ACOUSTIC RESULTS

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LONG-TERM GOALS

Our goal is to understand the propagation of low-frequency sound (10-1000 Hz) from the continental slope to the continental shelf including the effects of the ocean processes and bathymetric features that are associated with the shelfbreak. This understanding is key to achieving accurate sonar prediction in a shelf-slope littoral environment.

SCIENTIFIC OBJECTIVES

The acoustic objectives of the Shelfbreak PRIMER field study, which took place in a shelf-slope region south of New England, are: (1) To determine the effects of seasonal and mesoscale variability of the shelf-break frontal thermal structure on the transmission of sound from the slope to the shelf. (2) To relate the temporal and spatial variability of the acoustic propagation with the ocean variability in the frontal zone. (3) To obtain tomographic maps of the frontal region for use in the characterization of the ocean variability.

APPROACH

Our approach involves detailed and simultaneous measurements of physical oceanographic and acoustic properties during the contrasting summer and winter seasons. These measurements are being related to physical and acoustical modeling studies. Results from these modeling efforts, tested against the observations, should be broadly applicable to shelfbreak regions on a more global basis.

WORK COMPLETED

The field program surveying the frontal region was successfully completed in FY97. The field work included two intensive three-week experiments, one in July 1996 (summer) and the other one in February 1997 (winter). Specifically, each of the two experiments

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successfully employed a suite of observational techniques including an acoustic tomography array consisting of multiple transceivers/sources and two vertical hydrophone arrays (VLAs) straddling the shelf-break front, several high-resolution, three-dimensional surveys of the frontal region with a SeaSoar, a shelf-to-slope hydrographic section, and moored arrays of ADCPs, current meters and thermistors. The resultant data set is both comprehensive and of high quality, and will allow for gaining fundamental insights into the physics and variability of the slope-to-shelf sound propagation as it is influenced by the shelfbreak oceanographic processes and bathymetric features. The measurements are being supplemented by modeling studies, both oceanographic and acoustic. The detailed analysis of the data and the modeling has begun in earnest, with an initial emphasis being upon understanding the variability of the summer acoustic signals and its relation to the summer oceanographic condition.

All of the summer data from the moored systems has been reduced to useful quantities, and detailed modeling and analysis efforts have begun (Lynch et al., 1997). Initial acoustic data analysis and modeling have been performed to investigate (1) the temporal stability and variability of modal arrivals at the VLA due small-scale internal waves and mesoscale frontal features, and (2) the spatial variability of the upslope propagation as it is influenced by the shelfbreak front, the associated frontal ocean processes and the shoaling bathymetry. A quick assessment of these issues at this initial post-cruise stage can lay a good foundation for the follow-on work in quantifying the predictability, repeatability and space-time coherence of slope-to-shelf, low-frequency transmissions, and in establishing the forward relation between acoustic data and ocean variables which preambles the inverse mapping of the four-dimensional thermal structure of the frontal zone (Chiu and Lynch, 1997).

RESULTS

Though we have only had this rather extensive data set for a year, and though a large amount of our initial efforts have gone into routine data reduction and signal processing chores, there are still a few significant acoustic results that we can point to. Highlights of our initial acoustic analysis results include:

1. The times of arrival of the normal modes in summer are found to be stable over repeated transmissions, with small random fluctuations on the order of 10 ms due to the internal waves. A larger periodic perturbation of 30 ms rms produced by the semi-diurnal internal tides is also present. Although the amplitudes of the modes fade in and out on a time-scale of approximately 10 min., the peaks of the arrivals are easily identifiable and tractable to establish useful time-series of modal arrival time for mapping the ocean. The modal amplitude variability with the 10-min. time-scale is a result of mode coupling caused by internal solitary waves. The stability in arrival time as well as the amplitude fading caused by internal waves are illustrated in Fig. 1, where the variability of the arrival structure of two of the acoustic modes over 10 days are displayed. Aside from the short-scale fluctuations, the observed modal arrival

times show a decreasing trend over the 10 days as well as an increase between yearday 210 and 212. The oceanographic data reveals that the decreasing trend was related to the westward passage of cooler, fresher shelf water whereas the 3-day increase is related to an intrusion of a warm, saline small eddy.

2. Based on three cross-shelf summer temperature sections obtained by the SeaSoar in yeardays 208, 210 and 213, the variability of the modal arrival structure caused by a mesoscale event was computed using a broadband, coupled normal-mode propagation model (Chiu, 1996). This event corresponded to the intrusion of and later exit of a warm, saline small eddy, the remnant of a warm-core ring absorbed earlier by the Gulf Stream. This intrusion caused significant distortion in the frontal boundary. The modeled arrival structure for the three different days shows that the resultant travel-time changes are on the order of 100 ms, which is in agreement with the observed changes discussed above. This is good news to tomography since the mesoscale signal (100 ms) is considerably larger than the internal-wave noise (10 ms) and is predictable. The model results also show an increase of signal level during the warm intrusion. This model prediction of a warm enhancement is also consistent with the VLA observations.

3. The spatial structure of the summer sound field is significantly influenced by both the frontal zone and the sloping bottom. While the bottom affects the higher-order modes, the frontal structure controls the variability in the lower-order modes. Our model results show strong coupling between the modes as they propagate up the slope and through the front. Complex interactions between the low modes, cascading of some energy from high to intermediate modes, as well as the eventual stripping of the high modes by the reduced water-depth were found.

4. Using daily cross-front winter sound-speed sections provided by the Harvard group, an initial modeling study of the variability of the winter acoustic transmissions was also conducted. These winter sound-speed fields were the output of a Harvard ocean model run with assimilated winter oceanographic data. Unique to the winter sound-speed fields is the presence of complex double ducts (i.e., an upward refracting surface duct and a downward refracting bottom duct) on the slope. The double ducts merged into a single upward-refracting channel on the shelf. Large temporal variability is found in the modeled TL and modal coefficients. The depth of the boundary separating the surface and bottom ducts on the slope as well as its range variations are found to control, to a large extent, the initial partitioning of the acoustic energy (i.e., how much energy goes into and becomes trapped in the surface duct and how much remains in the bottom duct). The range variations of this boundary also causes significant mode coupling on the slope. Therefore, the temporal variability of this boundary is likely to be responsible for the large fluctuations in the slope-to-shelf winter sound field.

IMPACT/APPLICATIONS

The oceanographic data gathered in this field study should be valuable in helping to create a general environmental model of shelfbreak regions suitable for assessing present and designing future Navy systems, acoustic as well as nonacoustic. In conjunction with the oceanographic data, the acoustic data will allow for an in-depth understanding of the coherence of the sound field in a shelf-slope environment, as well as for validating whether tomography is a useful tool for coastal monitoring.

TRANSITIONS

This program is combined with 6.2 efforts in ocean data assimilation/nowcasting and acoustic prediction in a vertically integrated fashion, so that the transition to higher levels and systems should be facilitated.

RELATED PROJECTS

This project strongly compliments a number of other current projects including the two other PRIMER experiments (Haro Strait and the CMO high frequency), the SWARM experiment and the CMO experiment, which study different aspects of the coastal ocean variability and the relations to coastal acoustic fluctuations.

REFERENCES

Chiu, C.-S., J.H. Miller and J.F. Lynch (1996), 'Forward coupled-mode propagation modeling for coastal acoustic tomography,' J. Acoust. Soc. Am., 99(2), 793-802.

Chiu, C.-S. and J. F. Lynch (1997), 'Acoustic tomography in shallow water: issues, method and experimental results,' Proceedings of the International Conference on Shallow-Water Acoustics, Beijing, China, in press.

J.F. Lynch, G.G. Gawarkiewicz, C.-S. Chiu, R. Pickart, J.H. Miller, K.B. Smith, A. Robinson, K. Brink, R. Beardsley, B. Sperry, and G. Potty (1997), 'Shelfbreak PRIMER - An integrated acoustic and oceanographic field study in the mid-Atlantic Bight,' Proceedings of the International Conference on Shallow-Water Acoustics, Beijing, China, in press.

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